TABLE 4. BENCHMARK PRICE REGRESSION FOR C AUCTION

	Log of Price ($ per person in 1994)				
Variable	(1)	(2)	(3)	(4)	(5)
Eligible bidders' upfronts/total upfronts	1.564	1.456	1.849	1.852	1.562
	(1.38)	(1.32)	(1.76)	(1.65)	(1.39)
Log population density of buildout area	0.124	0.135	0.125	0.141	0.128
	(5.27)	(6.31)	(5.36)	(6.11)	(5.47)
Ten-year population growth 1990 to 1999	1.581	1.554	1.579	1.648	1.613
	(5.85)	(5.84)	(5.95)	(6.18)	(6.01)
Microwave links/hundred million people 1994	0.009	0.006	-0.020	-0.003	0.006
	(0.08)	(0.05)	(0.17)	(0.03)	(0.05)
Log of 1994 population	0.251	0.246	0.250	0.247	0.245
	(8.40)	(8.41)	(8.61)	(8.22)	(8.24)
Fraction of households with annual income > $35k	1.179	1.043	1.168	1.173	1.255
	(3.71)	(3.66)	(3.81)	(3.68)	(3.97)
Log of MTA price ($ per person in 1994)	0.116	0.116	0.119		0.115
	(2.79)	(3.00)	(2.90)		(2.78)
GSM technology in MTA	-0.066	-0.065	-0.063		-0.067
	(1.41)	(1.40)	(1.37)		(1.45)
Spatially correlated errors					0.361
					(2.96)
Constant	-3.152	-2.990	-3.388	-3.181	-3.121
	(2.87)	(2.83)	(3.26)	(2.94)	(2.87)
Data weighted by log 1994 population	No	No	Yes	No	No
Include Alaska, Guam, and American Samoa	No	Yes	No	No	No
Sample size	487	493	487	487	487
Adjusted R^2	0.531	0.535	0.551	0.523	0.538

Notes: t-statistics in parenthesis.

TABLE 5. SUMMARY STATISTICS FOR SYNERGY VARIABLES

Variable	Mean	Std Dev	Min	Max
Dollar winnings of marginal bidder (AB)	0.564	0.761	0.000	2.200
(C)	0.576	1.229	0.000	4.201
Dollar winnings of winning bidder (AB)	1.294	0.510	0.000	2.200
(C)	0.720	1.327	0.000	4.201
Absolute synergy of marginal bidder excluding cellular (AB)	5.977	7.813	0.000	17.259
(C)	5.292	6.515	0.000	16.795
Absolute synergy of marginal bidder including cellular (AB)	8.054	8.121	0.000	17.525
Relative synergy of marginal bidder excluding cellular (AB)	0.180	0.296	0.000	1.000
(C)	0.133	0.250	0.000	1.000
Relative synergy of marginal bidder including cellular (AB)	0.303	0.365	0.000	1.000
Absolute synergy of winning bidder excluding cellular (AB)	9.560	5.327	0.000	16.741
(C)	10.167	5.904	0.000	16.826
Absolute synergy of winning bidder including cellular (AB)	12.922	5.183	0.000	17.176
Relative synergy of winning bidder excluding cellular (C)	0.314	0.336	0.000	1.000

Notes: Excluding Alaska, Guam, and American Samoa. Sample size is 48 in AB auction and 487 in C auction.

TABLE 6. PRICE REGRESSION INCLUDING SYNERGIES FOR AB AUCTION

	Log of Price ($ per person in 1994)						
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Eligible bidders' upfronts/total upfronts	2.345	1.994	1.812	2.139	1.777	2.502	2.422
	(4.84)	(4.37)	(4.19)	(4.41)	(3.62)	(5.10)	(5.04)
Log population density of buildout area	0.237	0.241	0.258	0.252	0.204	0.278	0.273
	(2.70)	(3.20)	(3.64)	(3.13)	(2.55)	(3.01)	(3.04)
Ten-year population growth 1990 to 1999	3.718	3.353	2.139	3.644	2.264	3.866	3.716
	(3.65)	(3.78)	(2.42)	(3.85)	(2.24)	(3.77)	(3.71)
Microwave links/hundred million people 1994	-0.021	-2.375	-1.857	-2.605	-2.133	-1.694	-1.507
	(2.47)	(3.16)	(2.67)	(3.14)	(2.73)	(2.00)	(1.81)
Log of 1994 population	0.187	0.131	0.135	0.109	0.162	0.202	0.226
	(1.90)	(1.54)	(1.70)	(1.17)	(1.82)	(2.06)	(2.34)
Fraction of households with annual income > $35k	0.679	0.542	0.479	0.544	0.639	0.278	0.349
	(1.00)	(0.93)	(0.87)	(0.87)	(1.04)	(0.34)	(0.49)
Dollar winnings of marginal bidder		-0.100	-0.098	-0.218	-0.130		
		(1.22)	(1.32)	(1.82)	(1.38)		
Dollar winnings of winning bidder						0.193	0.216
						(1.54)	(1.76)
Absolute synergy of marginal bidder (excluding cellular)		0.030					
		(4.01)					
Absolute synergy of marginal bidder (including cellular)			0.033				
			(4.85)				
Relative synergy of marginal bidder (excluding cellular)				0.886			
				(3.03)			
Relative synergy of marginal bidder (including cellular)					0.679		
					(3.33)		
Absolute synergy of winning bidder (excluding cellular)						-0.009	
						(0.81)	
Absolute synergy of winning bidder (including cellular)							-0.019
							(1.68)
Constant	-3.960	-2.899	-2.931	-2.657	-2.952	-4.554	-4.761
	(2.74)	(2.30)	(2.49)	(1.92)	(2.22)	(3.10)	(3.32)
Adjusted R^2	0.599	0.706	0.741	0.664	0.677	0.610	0.630

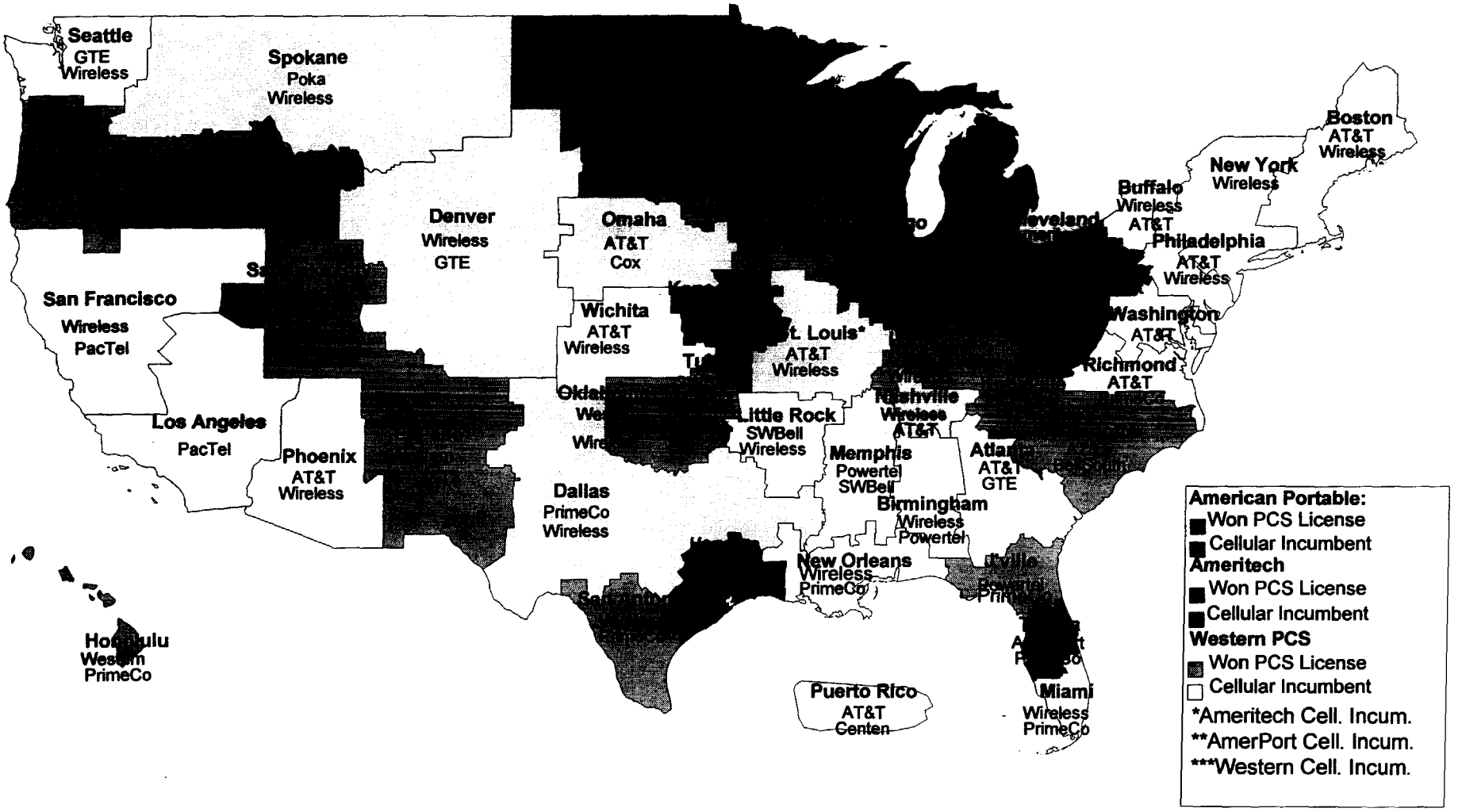
Notes: Excluding Alaska, Guam and American Samoa. Sample size is 48. t-statistics in parenthesis.

TABLE 7. PRICE REGRESSION INCLUDING SYNERGIES FOR C AUCTION

	Log of Price ($ per person)				
Variable	(1)	(2)	(3)	(4)	(5)
Eligible bidders' upfronts/total upfronts	1.564	1.237	1.331	1.457	1.597
	(1.38)	(1.11)	(1.19)	(1.29)	(1.40)
Log population density of buildout area	0.124	0.127	0.120	0.120	0.124
	(5.27)	(5.52)	(5.18)	(5.12)	(5.21)
Ten-year population growth 1990 to 1999	1.581	1.492	1.516	1.551	1.580
	(5.85)	(5.58)	(5.63)	(5.74)	(5.83)
Microwave links/hundred million people 1994	0.009	-0.013	-0.009	0.015	0.010
	(0.08)	(0.12)	(0.08)	(0.13)	(0.09)
Log of 1994 population	0.251	0.246	0.260	0.242	0.248
	(8.40)	(8.25)	(8.60)	(7.54)	(7.72)
Fraction of households with annual income > $35k	1.179	1.253	1.161	1.193	1.176
	(3.71)	(4.02)	(3.70)	(3.76)	(3.69)
Log of MTA price ($ per person in 1994)	0.116	0.113	0.106	0.114	0.116
	(2.79)	(2.75)	(2.54)	(2.73)	(2.78)
GSM technology in MTA	-0.066	-0.068	-0.071	-0.057	-0.066
	(1.41)	(1.47)	(1.52)	(1.20)	(1.40)
Dollar winnings of marginal bidder		-0.013	-0.025		
		(0.63)	(1.11)		
Dollar winnings of winning bidder				-0.002	0.007
				(0.12)	(0.31)
Absolute synergy of marginal bidder		0.016			
		(4.49)			
Relative synergy of marginal bidder			0.385		
			(3.64)		
Absolute synergy of winning bidder				0.008	
				(1.97)	
Relative synergy of winning bidder					-0.008
					(0.10)
Constant	-3.152	-2.927	-3.040	-3.013	-3.136
	(2.87)	(2.70)	(2.79)	(2.74)	(2.83)
Adjusted R^2	0.531	0.549	0.542	0.533	0.529

Notes: Excluding Alaska, Guam and American Samoa. Sample size is 487. t-statistics in parenthesis.

Figure 1
Winning Bidders and Sample Footprints in MTA Broadband PCS Auction



Excluding Alaska, Guam, American Samoa

Figure 2
Footprints of Top-10 Bidders
in C-Block Broadband PCS Auction

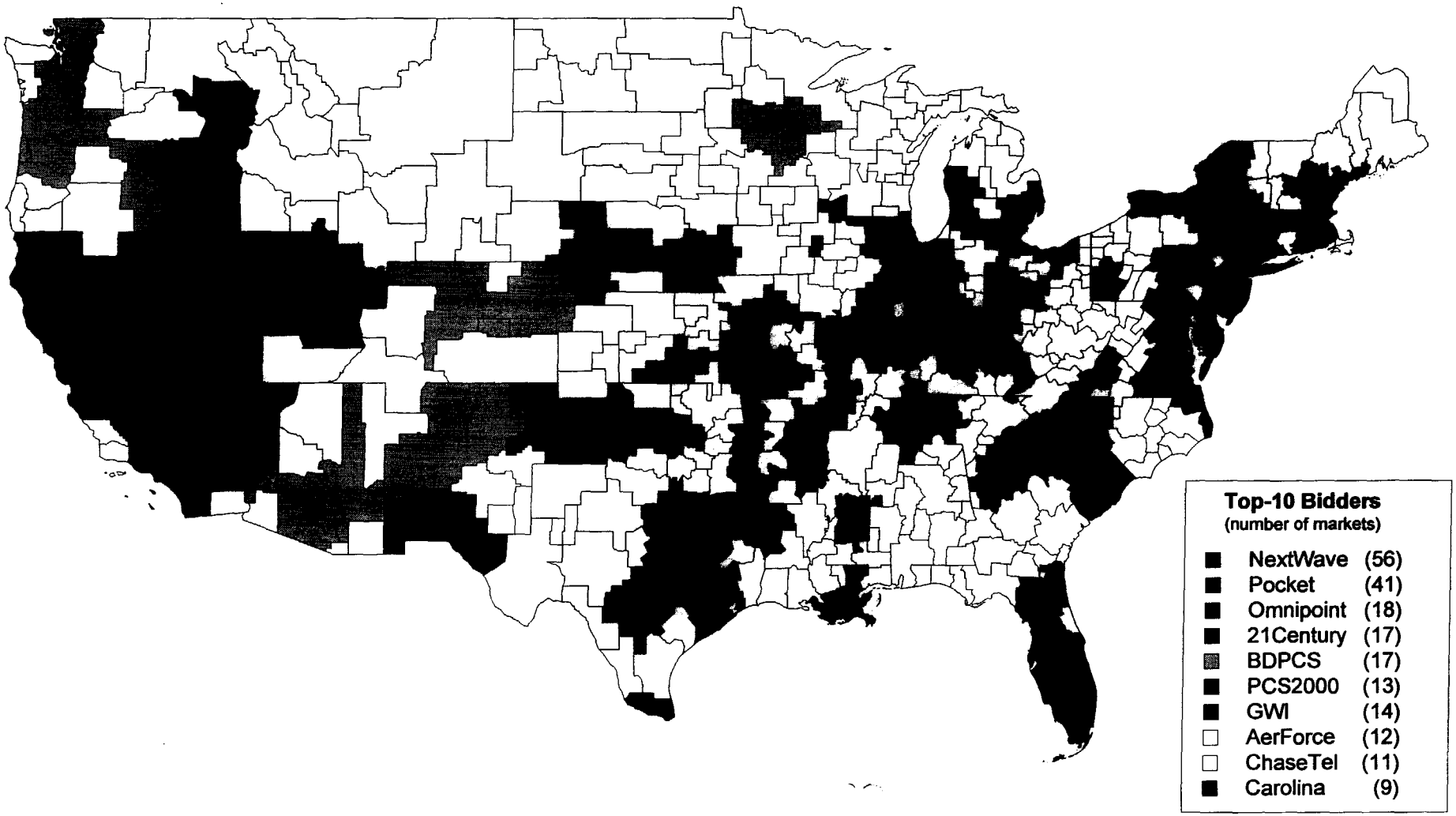
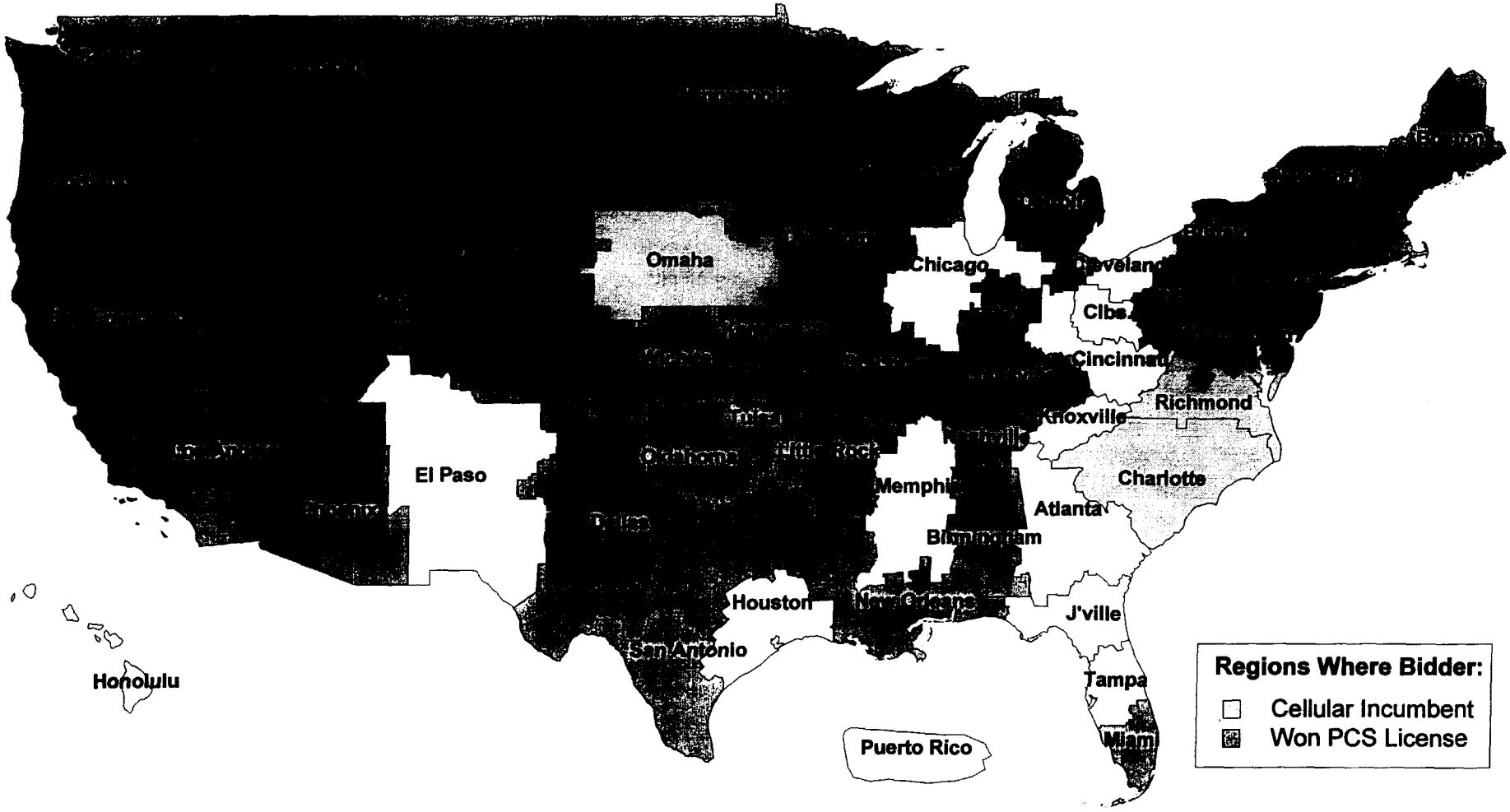
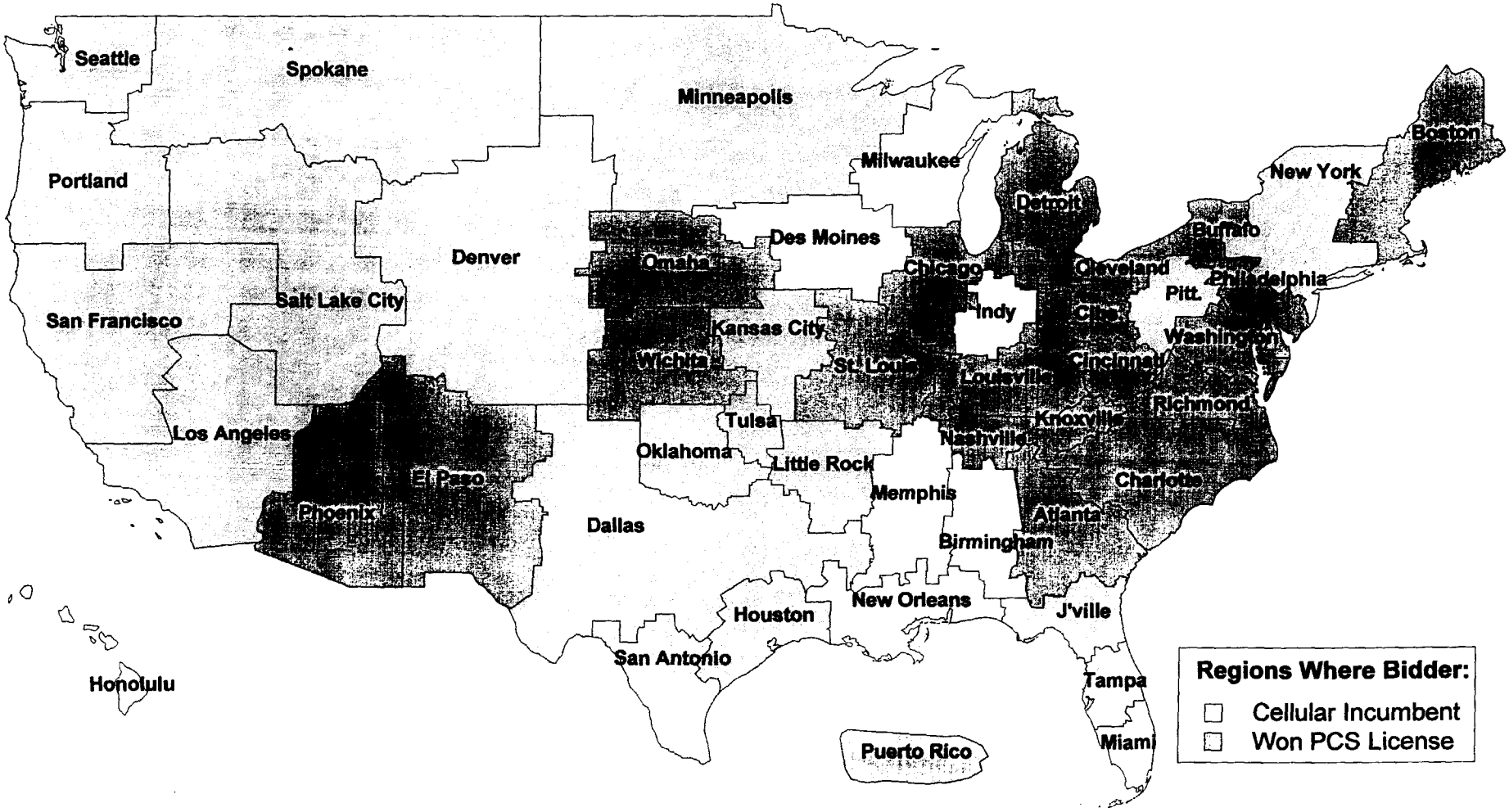


Figure 3
Footprint of WirelessCo
in MTA Broadband PCS Auction*



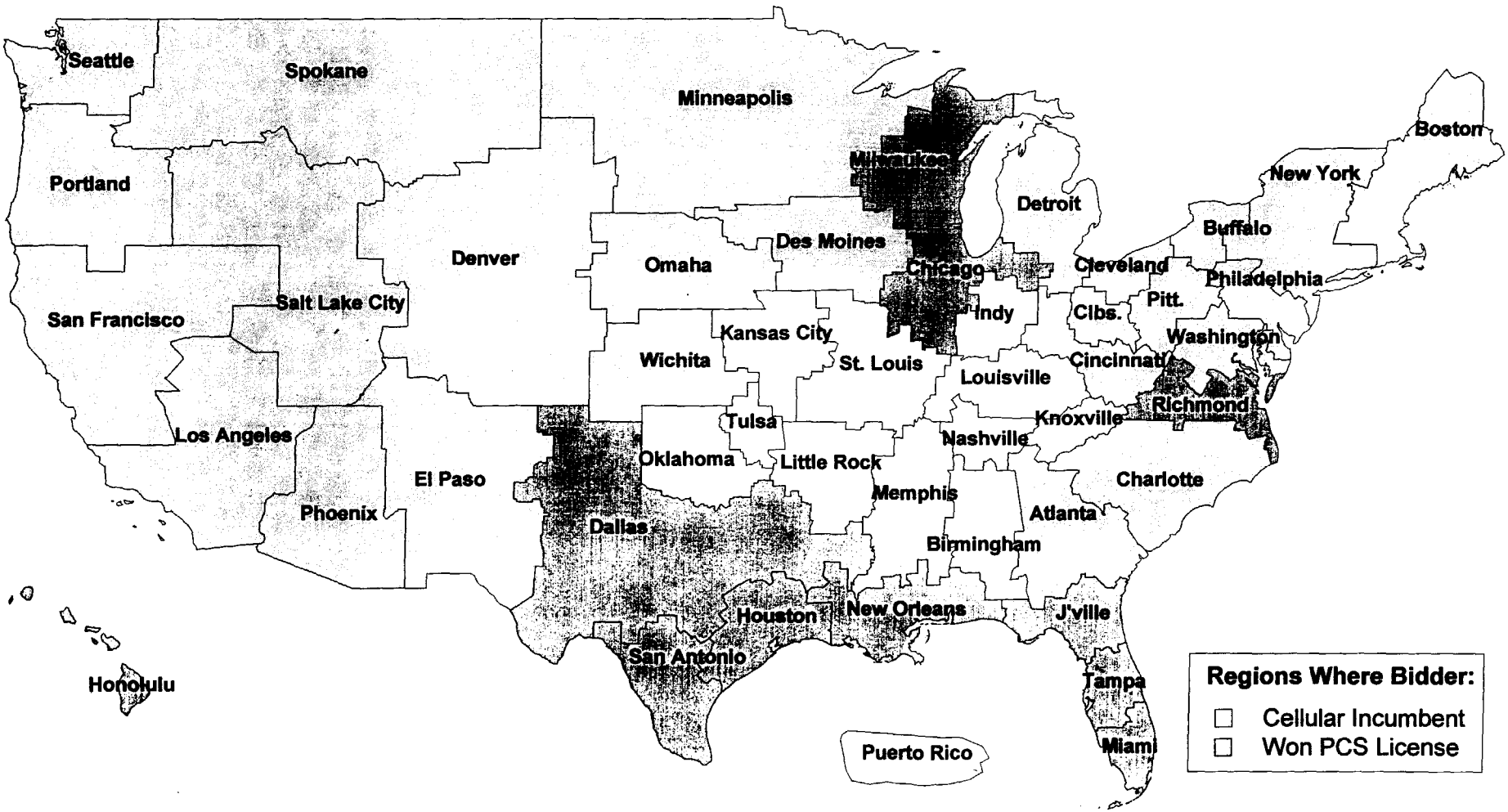
*Excluding Alaska, Guam, American Samoa

Figure 4
Footprint of AT&T
in MTA Broadband PCS Auction*



*Excluding Alaska, Guam, American Samoa

Figure 5
Footprint of PCS PrimeCo
in MTA Broadband PCS Auction*



*Excluding Alaska, Guam, American Samoa

The Efficiency of the FCC Spectrum Auctions

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The Efficiency of the FCC Spectrum Auctions

From July 1994 to July 1996, the Federal Communications Commission (FCC) conducted nine spectrum auctions, raising about $20 billion for the U.S. Treasury. The auctions assigned thousands of licenses to hundreds of firms. These firms are now in the process of creating the next generation of wireless communication services. The question addressed in this note is were the auctions efficient? Did they award the licenses to the firms best able to turn the spectrum into valuable services for consumers?

In addressing this question, I will focus on the narrow question of license assignment. Assignment is the second step in the process of utilizing spectrum. The first step is the allocation of the spectrum for licensing. The allocation defines the license (the frequency band, the geographic area, the time period, and the restrictions on use). I focus on assignment, since that is what the FCC spectrum auctions were asked to do. More general auctions that determine aspects of the allocation, such as band plans, have yet to be implemented.

Why should we care about auction efficiency? If resale is allowed, won't post-auction transactions fix any assignment inefficiencies? The answer is "yes" in a Coasean world without transaction costs. However, transaction costs are not zero. Post-auction transactions are often made difficult by strategic behavior between parties with private information and market power. The experience with the cellular lotteries is a case in point. It took a decade of negotiations and private auctions for the eventual service providers to acquire desirable packages of licenses from the lottery winners. Efficient auctions are possible before assignments are made, but may become impossible after an initial assignment. The problem is that the license holder exercises its substantial market power in the resale of the license.[1] For this reason, it is important to get the assignment right the first time.

All but two of the FCC auctions have used a simultaneous ascending design in which groups of related licenses are auctioned simultaneously over many rounds of bidding. In each round, bidders submit new higher bids on any of the licenses they desire, bumping the standing high bidder. The auction ends when a round passes without any bidding; that is, no bidder is willing to raise the price on any license. This design, proposed by Preston McAfee, Paul Milgrom, and Robert Wilson, is the natural extension of the English auction to multiple related goods. Its advantage over a sequence of English auctions is that it gives the bidders more flexibility in moving among license packages as prices change. As one license gets bid up, a bidder can shift to an alternative that represents a better value. In this way, bidders are able to arbitrage across substitutable licenses. Moreover, they can build packages of complementary licenses using the

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[1]Peter Cramton, Robert Gibbons & Paul Klemperer, Dissolving a Partnership Efficiently, 55 Econometrica 615 (1987).

information revealed in the process of bidding. Here I examine whether these potential advantages were realized.

The analysis is speculative. Since I do not observe the bidders actual valuations, it is impossible to say exactly how efficient the auctions were. Nonetheless, there is substantial evidence that the auctions were successful. I present this evidence and then identify the problems inherent in the auctions that suggest possible inefficiencies.

1 Evidence of Success

Revenue is a first sign of success. Auction revenues have been substantial, breaking $20 billion in the first two years.[2] Revenues have exceeded industry and government estimates. The simultaneous ascending auction may be partially responsible for the large revenues. By revealing information in the auction process, the winner's curse is reduced and the bidders can bid more aggressively.[3] Also, revenues may increase to the extent the design enables bidders to piece together more efficient packages of licenses.

Revenue maximization and efficiency are closely aligned goals. Indeed, in ex ante symmetric settings, the seller's expected revenue is maximized by assigning the goods to those with the highest values.[4] High prices are consistent with an efficient auction, since only bidders with high values are willing to pay high prices. Moreover, efficiency-minded governments should care about the revenues raised at auction, since auction revenues are less distortionary than the principal source of government revenues — taxation. Economists estimate that the welfare loss from increasing taxes in the U.S. is in the range of 17 to 56 cents per dollar of extra revenue raised.[5] Hence, in designing the auction, the government should be willing to accept some assignment inefficiency if the gain in revenues is sufficiently large.

A second indicator of success is that the auctions tended to generate market prices. Similar items sold for similar prices. In the narrowband auctions, the price differences among similar licenses were at most a few percent and often zero. In the first broadband auction, where two

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[2]All auction data are available from the FCC's web site at www.fcc.gov.

[3]Paul R. Milgrom & Robert J. Weber, A Theory of Auctions and Competitive Bidding, 50 Econometrica 1089 (1982).

[4]Lawrence M. Ausubel & Peter C. Cramton, Demand Reduction and Inefficiency in Multi-Unit Auctions (working paper, Univ. Maryland 1996).

[5]Charles L. Ballard, John B. Shoven, and John Whalley, General Equilibrium Computations of the Marginal Welfare Costs of Taxes in the United States, 75 American Economic Review 128 (1985).

licenses were sold in each market, the prices differed by less than one minimum bid increment in 42 of the 48 markets.

A third indicator of success is the formation of efficient license aggregations. Bidders did appear to piece together sensible license aggregations. This is clearest in the narrowband auctions. In the nationwide narrowband auction, bidders buying multiple bands preferred adjacent bands. The adjacency means that the buffer between bands can be used for transmission, thus increasing capacity. The two bidders that won multiple licenses were successful in buying adjacent bands. In the regional narrowband auction, the aggregation problem was more complicated. Several bidders had nationwide interests and these bidders would have to piece together a license in each of the five regions, preferably all on the same band. The bidders were remarkably successful in achieving these aggregations. Four of the six bands sold as nationwide aggregations. Bidders were able to win all five regions within the same band. Even in the two bands that were not sold as nationwide aggregations, bidders winning multiple licenses won geographically adjacent licenses within the same band.

Large aggregations were also formed in the MTA broadband auction. Bidders tended to win the same band when acquiring adjacent licenses. The three bidders with nationwide interests appear to have efficient geographic coverage when one includes their cellular holdings. The footprints of smaller bidders also seem consistent with the bidders' existing infrastructures. In the C-block auction, bidders were able to piece together contiguous footprints, although many bidders were interested in stand-alone markets.

Two studies analyze the MTA and BTA auction data to see if there is evidence of local synergies.[6] Consistent with local synergies, these studies find that bidders did pay more when competing with a bidder holding neighboring licenses. Hence, bidders did bid for synergistic gains, and judging by the final footprints, often obtained them.

The two essential features of the FCC auction design are (1) the use of multiple rounds, rather than a single sealed bid, and (2) simultaneous, rather than sequential sales. The goal of both of these features is to reveal information and then give the bidders the flexibility to respond to the information. There is substantial evidence that the auction was successful in revealing extensive information. Bidders had good information about both prices and assignments at a

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[6]Lawrence M. Ausubel, Peter Cramton, R. Preston McAfee & John McMillan, Synergies in Wireless Telephony: Evidence from the MTA Auction (working paper, Univ. Maryland 1996), and Patrick S. Moreton & Pablo T. Spiller, What's in the Air: Interlicense Synergies and Their Impact on the FCC's Broadband PCS License Auctions (working paper, Univ. California Berkeley 1996).

point in the auction where they had the flexibility to act on the information.[7] The probability that a high bidder would eventually win the market was high at the midpoint of each auction. Also the correlation between mid-auction and final prices was high in each auction. Information about prices and assignments improved throughout each auction, and was of high quality before bidders lost the flexibility to move to alternative packages.

The absence of resale also suggests that the auctions were highly efficient. In the first two years, there has been little resale. GTE is the one exception. Shortly after the MTA auction ended, GTE sold its MTA winnings for about what it paid for the licenses. Apparently there was a shift in corporate strategy away from PCS and toward cellular.

2 Potential Problems

Despite the apparent success of these auctions there are several potential problems that stand in the way of an efficient assignment.

Standard auctions at best assure that the bidder with the highest private value wins, rather than the bidder with the highest social value. Private and social values can diverge in these auctions, because the winners will be competing in a marketplace. One collection of winners may lead to a more collusive industry structure. For example, a license may be worth more to an incumbent than a new entrant, simply because of the greater market power the incumbent would enjoy without the new entrant. Recognizing this, the FCC limits the amount of spectrum any one firm can hold in any geographic area. Indeed, the FCC forbid incumbent cellular firms from bidding in their markets. Another example comes from the battle over technology standards in broadband PCS. Supporters of one standard may value a license more highly, if it creates a hole in the footprint of a competing standard, putting the competing standard at a competitive disadvantage. This may have been an issue in the fight over Chicago in the C-block auction. Chicago was a major hole in the GSM footprint, but was already covered by the CDMA footprint. However, a GSM bidder only got the license after a long fight with the largest CDMA bidder.

A second issue stems from the fact that these are multi-item auctions. The efficiency results from single-item auctions do not carry forward to the multi-item setting. In an ascending auction for a single item, each bidder has a dominant strategy of bidding up to its private valuation. Hence, the item always goes to the bidder with the highest value. If instead two identical items are being sold in a simultaneous ascending auction, then a bidder has an incentive to stop bidding for the second item before its marginal valuation is reached. Continuing to bid for two

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[7]Peter C. Cramton, The FCC Spectrum Auctions: An Early Assessment, 6 J. Econ. & Management Strategy forthcoming (1997).

items raises the price paid for the first.[8] As a result, the bidder with the highest value for the second item may be beaten by a bidder demanding just a single unit.

This logic is quite general. In multi-unit uniform-price auctions, every equilibrium is inefficient.[9] Bidders have an incentive to shade there bids for multiple units and the incentive to shade increases with the quantity being demanded. Hence, large bidders will shade more than small bidders. This differential shading creates an inefficiency. The small bidders will tend to inefficiently win licenses that should be won by the large bidders. The intuition for this result is analogous to why a monopolist's marginal revenue curve lies below its demand curve: bringing more units to market reduces the price paid on all units. In the auction, demanding more units raises the price paid on all units. Hence, the incentive to reduce demand.

To a large extent, the FCC spectrum auctions can be viewed as a uniform-price auction. Certainly, for licenses that are close substitutes, the simultaneous ascending auction has generated near uniform prices for similar items. Hence, large bidders in the spectrum auctions had an incentive to make room for smaller rivals.

Direct evidence of demand reduction was seen in the nationwide narrowband auction. The largest bidder, PageNet, reduced its demand from three of the large licenses to two, at a point when prices were still well below its marginal valuation for the third unit.[10] PageNet felt that, if it continued to demand a third license, it would drive up the prices on all the others to disadvantageously-high levels.

An examination of the bidding in the MTA broadband auction is suggestive that the largest bidders did drop out of certain markets at prices well below plausible values. Although this could be tacit collusion, myopic demand reduction is another explanation. Individual maximizing behavior would cause large bidders to make room for rivals to keep prices down.

Further evidence of demand reduction comes from the C-block auction. One large bidder defaulted on the down payment, so the FCC reauctioned the licenses. Interestingly, the licenses sold for 3% more than in the original auction. Consistent with demand reduction, NextWave, the largest winner in the C-block auction, bought 60% of the reauctioned spectrum. This occurred despite the fact that NextWave was not the second-highest bidder on any of these

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[8]For settings where this effect is strong, see Richard Engelbrecht-Wiggans & Charles M. Kahn, Multi-Unit Auctions with Uniform Prices (working paper, Univ. Illinois 1995).

[9]Ausubel & Cramton, *supra* note 4.

[10]I was a member of the PageNet bidding team. See Peter Cramton, Money Out of Thin Air: The Nationwide Narrowband PCS Auction, 4 J. Econ. & Management Strategy 267 (1995) for a detailed analysis of this auction.

licenses in the original auction. NextWave was able to bid aggressively in the reauction, knowing that its bidding would have no affect on prices in the original auction.

In auctions for identical items, the inefficiencies of demand reduction can be eliminated with a Vickrey auction. Alternatively, one can use Ausubel's ascending implementation of the static Vickrey auction, which has the additional advantages of an ascending-bid design.[11] However, the spectrum auctions were not for identical items, so Vickrey-type mechanisms were not practical.

There are good reasons to think that any inefficiencies caused by demand reduction in the FCC spectrum auctions are overstated. Demand reduction favors small bidders. Hence, small bidders, having less of an incentive to reduce demand, are able to win licenses they might otherwise not get. Demand reduction, then, fosters competition in the auction by encouraging the participation of small bidders. Perhaps more importantly, demand reduction may increase competition in the market for wireless services by increasing the number of competing firms.

The FCC, as mandated by Congress, has taken more direct steps to increase the number and diversity of winning firms. One-third of the broadband PCS spectrum has been set aside to small businesses. Preferences, both installment payments and bidding credits, also have been given to designated bidders in the other auctions. One might think that these set asides and preferences would be a prominent source of inefficiency. They let small firms win licenses that might otherwise go to large firms with higher values. However, the auction experience of the first two years suggests that the inefficiencies from preferences are small or even negative. In the regional narrowband auction, there is strong evidence that preferences to firms controlled by women or minorities raised revenues.[12] The preferences stimulated competition, forcing the large firms to pay more than they otherwise would. In the C-block broadband auction, which was a set aside for small businesses, competition was so intense that it resulted in prices that were about 80% higher than in the earlier MTA auction.[13] Revenues were certainly stimulated by the preferences to the small firms. Given the dramatic increase in revenues, it is hard to imagine that the assignment of these licenses to small firms involved substantial inefficiencies. These small firms expressed valuations well in excess of what the big firms paid in the prior auction.

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[11]Lawrence M. Ausubel, An Efficient Ascending-Bid Auction for Multiple Objects (working paper, Univ. Maryland 1995).

[12]Ian Ayres & Peter Cramton, Pursuing Deficit Reduction Through Diversity: A Case Study of How Affirmative Action at the FCC Increased Auction Competition, 48 Stanford Law Review 401 (1996).

[13]The 80% figure comes after netting out the 25% bidding credit and an additional credit of 30% derived from the value of the favorable installment payments.

Moreover, even if the small firms have lower values, the entrance of these small firms is likely to stimulate competition in the market for wireless services.

Another source of inefficiency in the spectrum auctions comes from the difficulties firms may have in piecing together efficient sets of licenses. The ability to form efficient aggregations is greatly enhanced by the excellent information about prices and assignments that is revealed in the auction process. Nonetheless, bidders may be hesitant to bid for synergistic gains they are unlikely to achieve. This exposure problem may lead to a failure to obtain efficient synergies. Similarly, bidders may bid for a synergistic gain, only to find they are inefficiently stuck with some individual licenses that do not make sense without others. Bykowsky et al. emphasize this potential problem and recommend package bidding — being able to bid on a collection of licenses, rather than just on individual licenses.[14] Although I agree that package bidding may be a good idea in settings where synergies are both strong and varied among the bidders, I do not think that the early spectrum auctions fit this case. Bidders in the narrowband auctions had little difficulty in forming efficient aggregations. In the MTA broadband auction, it appears that the individual markets were sufficiently large to capture most local synergies.

The C-block broadband auction provided the greatest challenge to bidders, since the BTA licenses were only about one-tenth the size of the MTAs and competition was much more intense. BTA-level synergies were certainly more important than the MTA-level synergies. However, I do not believe that the exposure problem stifled bidding or prevented firms from forming efficient aggregations. Early in the auction competition was sufficient that it was easy to move from one package to another. When this was difficult, bidders would focus their bidding in the major markets that were key to synergistic gains. For example, Chicago is a key market in obtaining a strong midwest presence. Hence, the fight over Chicago was resolved before the winning firm would bid seriously for the smaller complementary licenses neighboring Chicago. As a result of this strategy, major markets tended to receive final bids before the smaller markets.

Several firms did acquire clusters of adjacent licenses in the C-block auction. However, the bidding of the largest bidder, NextWave, suggests that local synergies were not large. NextWave pursued a strategy of acquiring major markets around the US. Spending nearly $5 billion, it had the resources to instead acquire large contiguous clusters in a few parts of the country, but chose not to do so. NextWave's strategy would not make sense if local synergies were large at the BTA level.

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[14]Mark M. Bykowsky, Robert J. Cull, and John O. Ledyard, Mutually Destructive Bidding: The FCC Auction Design Problem (working paper, CalTech 1995).

A final source of inefficiency comes not from bad assignments, but from delayed assignments. Each month of delay means a loss of consumer surplus. The simultaneous ascending auctions took a significant amount of time to conduct. Relatively simple auctions, like the nationwide narrowband auction, were done in a week. However, the more complex auctions with hundreds of bidders and licenses (the C-block, MDS, and SMR auctions) took about 80 bidding days.

The simultaneous ascending auction has a number of parameters (minimum bid increments, activity requirements, and rounds per day) that let the FCC control the pace of the auction. The parameters are adjusted during the auction to balance the goals of a timely and desirable assignment. The bidders need time to adjust strategies in light of information revealed in the bidding. Too much haste may lead to bidder error and inefficient assignments. Time also may be needed for bidders to line up additional capital if prices are higher than expected. Certainly, these spectrum auctions could have been conducted more quickly, but probably not without reducing the efficiency of the assignment.

3 Conclusion

Any auction would look good relative to the FCC's past experience with comparative hearings and lotteries. Hence, it is remarkable that the FCC chose an innovative and untested design to auction the spectrum. Fortunately, there is now substantial evidence that the simultaneous ascending auction worked well. It raised large revenues. It revealed critical information in the process of bidding and gave bidders the flexibility to adjust strategies in response to new information. As a result, similar licenses sold for similar prices, and bidders were able to piece together sensible sets of licenses.

The setting of the spectrum auctions is too complex to guarantee full efficiency. Bidders with the highest private values may not have the highest social values. To keep prices low, large bidders may reduce demand, inefficiently making room for smaller rivals. Preferences for designated bidders may distort assignments. And bidders may hesitate to bid for synergistic combinations for fear of not obtaining the synergies. Nonetheless, an examination of the bidding suggests that these problems, although present, probably did not lead to large inefficiencies. Moreover, the cures to these problems have side-effects that may be worse than the disease.

The spectrum auctions are a major step toward creating a market for spectrum. The greatest room for improvement lies not in the assignment of licenses, but in the allocation process. Some allocations, like PCS, allow flexible use, but others, such as broadcasting, do not. Further steps need to be taken to assure that market forces, not political lobbying, determine spectrum use.

Deficit Reduction Through Diversity: How Affirmative Action at the FCC Increased Auction Competition

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ARTICLES

Deficit Reduction Through Diversity: How Affirmative Action at the FCC Increased Auction Competition

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In recent auctions for paging licenses, the Federal Communications Commission has granted businesses owned by minorities and women substantial bidding credits. In this article, Professors Ayres and Cramton analyze a particular auction and argue that the affirmative action bidding preferences, by increasing competition among auction participants, increased the government's revenue by $45 million. Subsidizing the participation of new bidders can induce established bidders to bid more aggressively. The authors conclude that this revenue-enhancing effect does not provide a sufficient constitutional justification for affirmative action—but when such justification is independently present, affirmative actions can cost the government much less than is currently thought.

INTRODUCTION

Congress first authorized the Federal Communications Commission ("FCC") to auction licenses for slices of the radio spectrum in 1993.[1] Since then, FCC auctions have raised nearly $9 billion.[2] As part of these auctions, Congress required the FCC to "ensure that . . . businesses owned by members of minority groups and women are given the opportunity to participate in the provision of spectrum-based services, and, for such purposes, consider the use of tax certificates, bidding preferences, and other procedures."[3] Relying on this statutory mandate, the FCC has at times granted substantial bidding preferences to firms controlled by women or minorities ("designated bidders").

This article focuses on the "regional narrowband" auction of thirty licenses for use in advanced paging services (which might, for example, both transmit and receive messages).[4] Designated bidders in the regional narrowband auction were allowed to pay for any of the licenses in installments over ten years at a favorable interest rate[5] and, on ten of the thirty narrowband licenses, were granted a 40 percent bidding credit.[6] When both preferences applied, the combined effect was that favored bidders had to pay the government only 50 percent of a winning bid.[7]

The FCC's affirmative action has been criticized as a huge giveaway,[8] but this article will show that the bidding preferences increased the government's revenue by more than 12 percent—an increase in total revenues of nearly $45 million. Although at first blush it seems that allowing designated bidders to pay fifty cents on the dollar would necessarily reduce the government's revenue, we will show that subsidizing designated bidders created extra competition in the auctions and induced the established, unsubsidized firms to bid higher.

The unsubsidized firms bid more both because they had fewer licenses for which to compete (once the substantial designated preferences effectively set aside ten of the thirty licenses) and because they had to compete against the subsidized designated bidders crossing over to bid on non-set-aside licenses. The regional narrowband auction is a vivid example of how subsidized bids by a minority- or female-controlled firm can substantially increase the price that the government receives from a non-designated firm. Early in the auction, a non-designated firm (PageMart), attempting to aggregate a national license by bidding for all five regional licenses on a particular frequency block, had succeeded in outbidding all of its non-designated rivals by offering to pay a total of $76 million.[9] However, a minority-controlled bidder, PCS Development, entered the fray, upping the ante more than a dozen times and forcing PageMart ultimately to bid $93 million to win the licenses. The additional competition from the minority-controlled firm increased the government's revenue by $16 million.[10] The extra revenue the government earned from unsubsidized win-

1. 47 U.S.C. § 309(j) (Supp. 1995). The FCC previously awarded licenses by lottery or by comparative hearing. *See* text accompanying notes 172-173 *infra*.

2. *See* Peter C. Cramton, The PCS Spectrum Auctions: An Early Assessment 2 (Aug. 25, 1995) (unpublished manuscript, on file with the *Stanford Law Review*). The auctioned frequencies were made available to personal communication services ("PCS") providers. The FCC auctioned 10 nationwide narrowband PCS licenses in July 1994, 30 regional narrowband licenses in October and November 1994, and 99 broadband licenses for Major Trading Areas ("MTAs") from December through March 1995. *Id.* A second broadband auction for 493 licenses was scheduled for the spring of 1995 but was delayed by litigation over the FCC's bidding preferences for small businesses, women, and minorities. The auction ultimately was rescheduled for December 18, 1995. *See* note 128 *infra*.

3. 47 U.S.C. § 309(j)(4)(D) (Supp. 1995).

4. Because of their narrow bandwidth, however, these licenses are ill-suited for cellular or other real-time voice services: Cellular services require broadband (30 MHz) transmission, up to 600 times wider than the spectrum assigned to narrowband (50 kHz), while narrowband transmission is sufficient for delayed voice or data services. For example, downloading phone messages to a pager for later playback only requires a narrowband license. *See* Cramton, *supra* note 2, at 2.

5. *See* notes 51-55 *infra* and accompanying text for a description of the installment subsidy.

6. For example, due to the bidding credit, a designated bidder who won a license with a bid of $10 million would only owe the government $6 million. See text accompanying notes 44-50 *infra* for a detailed description of the specific frequency blocks to which these bidding credits applied.

7. *See* notes 61-63 *infra* and accompanying text for a calculation of the combined subsidies. If a designated bidder prevailed on one of the 20 licenses to which the 40% bidding credit did not apply, the government would receive an estimated 84% of the winning bid. *Id.*

8. *See, e.g.*, Jonathan Rauch, *Color TV*, THE NEW REPUBLIC, Dec. 19, 1994, at 9.

9. Even though no other firm raised PageMart's bids for several rounds, the simultaneous auction was designed to remain open until there were no new bids on any of the 30 licenses. *See* notes 45-46 *infra* and accompanying text. The final results of the auction appear in Table 3 *infra*.

10. *See* text accompanying note 83 *infra*.

ning bidders, such as PageMart, more than offset the subsidy to the designated bidders. Far from being a giveaway, affirmative action bidding preferences induced competition that prevented established firms from buying the airwaves at substantial discounts.

Our positive thesis is that affirmative action can enhance bidding competition and thereby increase revenue. Of course, this can only occur where competition among unsubsidized bidders would otherwise fail—for example, if there were a shortage of serious unsubsidized bidders or if bidders were to collude, explicitly or tacitly. Moreover, affirmative action's capacity to enhance competition is not limited to situations where the government is a seller. Indeed, the government buys far more than it sells, and affirmative action bidding preferences may reduce the cost of government acquisitions for the same reasons. When competing against subsidized bidders for government contracts, unsubsidized suppliers may lower their bids to increase their chances of winning the new contract.

More broadly, this analysis reveals a potential profit motive for private affirmative action. Just as competition among unsubsidized bidders may not maximize the auction organizer's revenue, competition among workers in some labor markets may not maximize employer profits. If competition among the strongest job applicants is not sufficient for the employer to extract all the gains of trade from the employment relationship, then employers may have an incentive to subsidize weaker candidates, thereby inducing stronger applicants to work harder or for a lower wage.[11]

While we show that affirmative action at the FCC's regional narrowband auction decreased the budget deficit (and might plausibly be used to reduce government procurement costs or to increase private profits), we do not argue that this revenue-enhancing effect is normatively *sufficient* to justify race- or gender-conscious decisionmaking. Indeed, using affirmative action to reduce the budget deficit would not satisfy either prong of *Adarand*'s strict scrutiny analysis:[12] Raising additional revenues is not a "compelling governmental purpose," and race-conscious means are not "narrowly tailored" to further that goal—race-neutral subsidies of small bidders would also likely be able to enhance the government fisc.

The revenue-enhancing effect, however, shows that affirmative action may cost the government less than previously thought. Demonstrating that such measures need not drain the treasury might be imperative for garnering legislative support. Thus, even if the revenue effect is not constitutionally sufficient to justify affirmative action, it may establish a necessary condition for politically justifying it.

The relevance of showing that affirmative action subsidies do not burden the treasury is apparent in current debates surrounding the various California

11. The troubling aspects of describing beneficiaries of affirmative action as "weaker candidates" are discussed *infra* at note 20.

12. Adarand Constr. v. Pena, 115 S. Ct. 2097 (1995) (holding that federal government affirmative action measures must pass strict scrutiny).

ballot initiatives to end state-sponsored affirmative action.[13] Proponents of these initiatives trumpet the nonpartisan estimates of the legislative analyst office that the state could save tens of millions of dollars annually by eliminating affirmative action.[14] These estimates assume that affirmative action increases the state's procurement costs whenever the state rejects a low bid to contract with historically disadvantaged firms.[15] But the take-home lesson of this article is that affirmative action may not cost nearly as much as such crude estimates. In the procurement context, there is anecdotal evidence that affirmative action bidding subsidies have destabilized tacit collusion among unsubsidized bidders and have thereby reduced the average cost of procurement. The all-too-familiar story of a few government suppliers entering inflated, collusive bids can be rewritten by affirmative action initiatives that subsidize new entrants and thereby spur more competition. An unidentified source at the California Department of Transportation reports that affirmative action has forced the price of winning construction bids to approach independent estimates of construction costs.[16]

But in emphasizing the normative relevance of enhanced bidding competition, it is also important to recognize that increased government revenue (or decreased government cost) does not imply that affirmative action subsidies promote efficiency. Indeed, the beneficial impact on the government's revenue from bidding subsidies will often come at a cost of some economic inefficiency—in equilibrium some contracts will be awarded to lower-valuing buyers (or higher-cost producers). While enhancing market competition usually increases efficiency, enhancing bidding competition through affirmative action subsidies simply allows the government to capture more of the gains of trade, usually at the cost of some inefficiency.[17] These inefficiencies, however, may be short-term if affirmative action promotes new entry that stimulates subse-

13. Several constitutional amendments concerning affirmative action have been filed with the California Attorney General for potential inclusion on the 1996 ballot. *See, e.g.*, Carl Ingram, *Affirmative Action Measures Threaten to Confuse Voters*, L.A. TIMES, July 3, 1995, at A3. Perhaps the most prominent of these is the California Civil Rights Initiative. *See The Great Debate Over Affirmative Action*, S.F. CHRON., Jan. 19, 1995, at A21.

14. William F. Buckley, *California's New Fight Over Civil Rights*, THE FRESNO BEE, Jan. 12, 1994, at B7.

15. For example, 16% of prime contractors responding to a 1986 survey by the California Construction Industry Research Board reported submitting the lowest bid on a federal project within the previous year but losing that project because of failure to meet affirmative action goals. These contractors reported that the winning bids were on average 5.3% higher than their own low bids. Charles Oliver, *Making California Colorblind?*, INVESTOR'S BUS. DAILY, Mar. 21, 1995, at A1, A2.

16. Confidential conversation with Ayres (1995).

17. To the extent that the subsidies increase revenue, the cost due to an inefficient assignment may be more than offset by the efficiency gain from raising revenues in a nondistortionary way. Governments need revenue, which is normally raised by taxation. Taxation, however, is distortionary. Economists estimate that the welfare loss from increasing taxes is in the range of 17 to 56 cents per dollar of extra revenue raised. *See* Charles L. Ballard, John B. Shoven & John Whalley, *General Equilibrium Computations of the Marginal Welfare Costs of Taxes in the United States*, AM. ECON. REV., Mar. 1985, at 128. Hence, even if the subsidies causes substantial inefficiencies in assignments, the welfare loss may be more than offset by a reduction in distortionary taxes. Governments should care about the revenue consequences of the auction design. *See* MICHAEL H. ROTHKOPF & RONALD M. HARSTAD, RECONCILING EFFICIENCY ARGUMENTS IN TAXATION AND PUBLIC SECTOR RESOURCE LEASING 1 (RUTCOR Research Report No. 66-90, 1990).

quent, unsubsidized market competition. Moreover, there may be no efficiency loss if lower designated bids simply reflect inability to pay (possibly caused by discrimination in credit markets) rather than less prospective ability to supply paging services.[18]

This paper is divided into four parts. Part I analyzes a series of game-theoretic examples to show how bidding preferences could enhance government revenue. In Part II, we illustrate how this occurred in the FCC's regional narrowband auction. Part III identifies a limited set of other contexts where affirmative action might be profitable. Finally, Part IV explores the normative and legal implications of affirmative action's revenue-enhancing effect.

I. THEORY

An auction with few bidders can generate selling prices substantially below the highest bidders' valuations. Foreclosure sales, for example, are notorious for this type of competitive failure: If only two bidders show up to bid on a single piece of property, the bidder with the higher valuation will only have to outbid her counterpart—even if the lower bid is only a fraction of the property's true market value.[19]

Giving bidding preferences to weak bidders[20] can increase auction revenues by inducing stronger bidders to bid more aggressively. Bidding preferences can enhance both "intragroup" and "intergroup" auction competition: Bidding preferences that reduce the quantity available to strong bidders may cause them to bid more aggressively among themselves (intragroup competition); subsidizing weak bidders may allow them to challenge strong bidders (intergroup competition).[21]

Giving bidding preferences to relatively weak bidders, however, is likely to enhance expected revenue only if: (1) there is insufficient competition among the highest valuing bidders, *and* (2) the seller is able to identify stable classes of bidders who are likely to have relatively low valuations. The first of these conditions is likely to hold where there are few bidders relative to the number of goods auctioned. The auction price is determined by the value of the last bidder to drop out, and the reservation price of this last bidder is likely to be lower when fewer bidders participate in an auction. Conversely, if there are a large number of relatively high-value bidders active in an auction, then competition among these bidders by itself will allow the seller to extract most of the gains from trade, obviating the need for bidding subsidies.[22]

But even having as many as four excess bidders may not be sufficient to extract all of the gains of trade. For example, assume that four widgets are being auctioned to a group of bidders who have reservation prices uniformly distributed between $0 and $100 (and that the seller's reservation price is $0). The percentage of the gains of trade that the seller captures crucially depends on the number of bidders in excess of the number of items being sold. As shown in Table 1, even with eight bidders the seller will only capture 61.5 percent of the expected gains from trade. Our analysis shows that subsidizing weak bidders can increase the seller's yield by inducing the highest valuers to bid more.

TABLE 1. EFFECT OF EXCESS BIDDERS ON SELLER'S EXPECTED PROFITS[23]

Number of Bidders	Expected Percentage of Gains from Trade Accruing to Seller
1	0.0
2	0.0
3	0.0
4	0.0
5	28.6
6	44.4
7	54.5
8	61.5
9	66.7

18. A final normative implication of using affirmative action to enhance competition concerns the legality of affirmative action by private employers under Title VII. That some private employers may institute affirmative action programs solely to increase profits may cause courts to scrutinize private affirmative action more closely, in order to distinguish plans that seek to remedy past discrimination from those motivated solely by a desire to increase profits. *See* notes 165-168 *infra* and accompanying text.

19. Similarly, in bankruptcy, secured creditors are interested in generating enough income to cover their debt, rather than in maximizing the debtor's residual value. In liquidating or reorganizing debtors, creditors have no incentive to sell corporate assets for more than the value of their claims. *See* Philippe Aghion, Oliver Hart & John Moore, *The Economics of Bankruptcy Reform*, 8 J.L. ECON. & ORG. 523, 525-28 (1992) (discussing obstacles to attainment of full market value for assets auctioned pursuant to a bankruptcy proceeding).

20. A "weak" bidder is a bidder who has a lower expected reservation price. The highest amount that a bidder is willing or able to pay is that bidder's "reservation price." *See* Jennifer Gerarda Brown & Ian Ayres, *Economic Rationales for Mediation*, 80 VA. L. REV. 323, 331 n.26 (1994). In this article, we assume that a bidder knows its own reservation price, but that sellers and other bidders are imperfectly informed and can only form expectations of the bidder's reservation price.

In the regional narrowband auction, affirmative action subsidies were premised on the FCC's belief that firms controlled by women and minorities had a lower ability to pay for licenses, in part because of discrimination in credit markets. Implementation of Section 309(j) of the Communications Act—Competitive Bidding, 9 F.C.C.R. 2941, 2968-71 (1994) (Third Report and Order, PP Docket No. 93-253) [hereinafter Third Report & Order].

Our description of designated firms as relatively weak bidders is intended only to connote that these bidders may have lower expected reservation prices. Making this assumption without sufficient empirical support risks a disabling type of stereotype. As Justice Clarence Thomas recently wrote: "It never ceases to amaze me that the courts are so willing to assume that anything that is predominantly black must be inferior." Missouri v. Jenkins, 115 S. Ct. 2038, 2061 (1995) (Thomas, J., concurring). However, the FCC's difficulties in promoting diverse participation and the results of the narrowband auction themselves support the inference that designated bidders had lower reservation prices. *See* Table 3 *infra*.

21. By granting designated bidders a 50% subsidy on two frequency blocks, the FCC effectively excluded non-designated bids, thereby forcing non-designated bidders to bid more aggressively on the remaining blocks (intragroup competition). *See* notes 49-50 *infra* and accompanying text. In addition, the FCC fostered intergroup competition by giving designated bidders a 16% subsidy on the four other frequency blocks. *Id.*

22. R. Preston McAfee & John McMillan, *Auctions and Bidding*, 25 J. ECON. LITERATURE 699, 703 (1987). Formally, if the valuations for a group of high valuers is drawn from the same probability distribution, then the expected auction price will asymptote to the highest bidder valuation as the size of the group becomes arbitrarily large. *Id.* at 711.

23. Because the seller's reservation price is $0, the expected gain from trade is simply the expected high value among a certain number of bidders. Statisticians call this value the first-order

The second condition for profitably subsidizing weak bidders does not require that sellers know either the bidders' reservation prices or their expected reservation prices. But sellers must be able to estimate the expected difference between the reservation prices of at least two stable groups of bidders in order to identify the weaker group and to calculate the size of the subsidy that might enhance revenue.[24] Sellers would want to distinguish between expected high and low value bidders because subsidizing high-value bidders would normally reduce the expected auction revenues.[25]

The narrowband PCS auctions likely satisfied both conditions: an insufficient number of higher value bidders and a readily identifiable class of weak bidders. Because the demand for, and the supply of, these advanced paging services are unproven, capital markets shied away from financing companies that did not already have significant prior industry experience. This capital market constraint by itself could explain why competition among nonpreferred firms would be insufficient to drive bidding toward the highest bidders' reservation prices. Since designated bidders are disproportionally underrepresented in communications technology markets, the government could reasonably expect that these capital market constraints would bind designated bidders all the more. Thus, the FCC could reasonably conclude that designated bidders would have lower reservation prices. Nonetheless, the government's informational problem was far from trivial: While the government could reasonably expect that designated bidders would be weaker, it is not clear that they knew how much weaker. And knowing the magnitude of the difference in reservation prices between strong and weak bidders is critical to calculating the size of the subsidy necessary to increase expected revenue.

To underscore how difficult it is to meet these two conditions, the reader should keep in mind that few real world sellers find it worthwhile to subsidize weak bidders to increase their expected revenue.[26] For example, one would think in the context of art auctions that subsidizing museums (which are often thought to have constrained budgets) might be a way to induce private collectors to bid more. But auction houses normally do not subsidize weak bidders. The FCC, however, has several advantages over private sellers.[27] Most importantly, the FCC can prohibit subsidized bidders from reselling to unsubsidized firms.[28] The resale possibility greatly exacerbates the private seller's informational problem: It is much more difficult to identify a class of weak bidders because a weak bidder may in effect just be purchasing on behalf of the stronger, unsubsidized bidders. By prohibiting (or restricting) resale of the designated bidders' licenses to non-designated firms, the government by fiat can eliminate the unraveling effects of resales. The FCC's decision to sell more licenses than a profit-maximizing monopolist also increased the chance that affirmative action would raise revenue: If the FCC were only interested in maximizing the auction revenue, it would have only auctioned one license per region because firms bidding for the right to have a monopoly would pay much more than firms bidding for the right to compete with many other firms. While there may have been enough established firms to create a competitive auction for single licenses, the FCC's decision to sell six narrowband licenses in each of the five regions, in addition to the ten nationwide, created the need to bring more bidders to the table to enhance auction competition.

To illustrate how affirmative action can enhance bidding competition, we begin with a series of examples showing how a particular set-aside or bidding credit increases expected revenue, without addressing whether the seller has adequate information to choose the right subsidy. In Part I.D we will then explain how an imperfectly informed seller could calculate revenue-enhancing subsidies.

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statistic. The expected price in an auction of four items is the fifth-order statistic. To derive Table 1, we simply calculated the first- through fifth-order statistics for different numbers of bidders (which are well-defined for the uniform distribution); we then divided the fifth-order statistic by the sum of the first- through fourth-order statistics and multiplied the result by the number of items being auctioned, which yielded the expected percentage of gains from trade accruing to the seller (as auction revenue). For example, with $n = 9$ bidders, the expected value of the first- to fifth-order statistics are 0.9, 0.8, 0.7, 0.6, and 0.5. Revenue is equal to $4 \times (0.5) = 2$ and the expected gains from trade are $0.9 + 0.8 + 0.7 + 0.6 = 3$, so the seller's share is $2/3 = 66.7\%$. For a technical discussion of expected bids, see Jeremy Bulow & John Roberts, *The Simple Economics of Optimal Auctions*, 97 J. POL. ECON. 1060, 1086-89 (1989).

24. Game-theorists use the term "private valuation" auction to refer to auctions in which each bidder knows her private valuation, but the seller and the other bidders know only the probability distribution from which this valuation is drawn. Private valuation models are usually contrasted with "common valuation" models, in which all bidders have a single, common value for the good being auctioned, but have imperfect information about what this value will turn out to be. *See* Peter Cramton & Alan Schwartz, *Using Auction Theory to Inform Takeover Regulation*, 7 J.L. ECON. & ORG. 27, 28-29 (1991) (distinguishing between common value and independent private value auctions). While the narrowband auctions certainly have some aspects of a common valuation game, bidders' idiosyncratic entrepreneurial abilities inject a private valuation component which can give rise to a revenue-enhancing effect—that is, bidders "derive different surplus from winning." *Id.* at 29 n.4.

25. Giving bidding subsidies to a bidder who is likely to have a high valuation would *reduce* auction competition and lead to lower expected revenues because such a subsidy would entrench the strong/subsidized bidder and reduce the amount that this bidder would likely have to pay to win the auction.

If the seller believes that bidders' demand for multiple items to be auctioned is sufficiently inelastic, then the seller may want to set aside one or more of the items even if she cannot distinguish between higher- and lower-valuing bidders. Indeed, increased revenue from quantity reduction on the auctions without set-asides might be greater than the reduced revenue that the seller would expect to receive from the set-aside license. Where the seller cannot identify relatively weak bidders—from the seller's perspective all bidders are symmetric ex ante—arbitrary preferences will not maximize expected revenue. Under these conditions, the revenue-maximizing multi-object auction is symmetric. *See generally* Eric Maskin & John Riley, *Optimal Multi-unit Auctions*, *in* THE ECONOMICS OF MISSING MARKETS, INFORMATION, AND GAMES 312 (Frank Hahn ed., 1989).

26. Sellers often do establish minimum auction bids (often referred to as the "reserve price') above their own value, which has the effect of subsidizing themselves as a particular type of weak bidder. *See* note 35 *infra* and accompanying text (discussing effect of seller reserve prices). We revisit this informational problem when we assess the analogous use of affirmative action by private employers. *See* notes 142-147 *infra* and accompanying text.

27. The Robinson-Patman Act's (rarely enforced) prohibition against price discrimination may deter sellers from subsidizing weak bidders—especially as here when bidders subsequently compete with each other. Robinson-Patman Act, 15 U.S.C. § 13a (1994).

28. The FCC rules do not specifically address the leasing of licenses from a designated bidder to a non-designated bidder. *See* Third Report and Order, *supra* note 20, at ¶¶ 66-89. This failure may increase the possibility of a sham designated bidder. However, if the lease was structured in a way that the designated bidder effectively lost control of the license, then presumably the FCC would prohibit the arrangement, since it would amount to a change in control.

In the initial series of examples, we assume that four firms are bidding to purchase two licenses and that each bidder is only interested in purchasing a single license.[29] The four bidders have different reservation prices: The two strong bidders ($Strong_1$ and $Strong_2$) are willing to bid up to $110 and $90 respectively, and the two weak bidders ($Weak_1$ and $Weak_2$) are willing to bid up to $60 and $40 respectively.

Using a traditional English (or open ascending) auction, in which the price rises until a single buyer remains, the government should expect to earn slightly more than $120. The two strong bidders only need to slightly outbid the $60 weak bidder in order to win licenses. Even though the strong bidders would have been willing, if needed, to bid more, they have no reason to compete against each other; the supply of licenses at this price is sufficient to satisfy their own demand. Using this auction as a benchmark, we will now consider a series of examples in which bidding credits and set-asides generate more than $120 in government revenue by inducing the strong bidders to bid more aggressively.

A. *Set-Asides Can Enhance Intragroup Competition Among Strong Bidders*

Sellers can induce more competition among strong bidders, and therefore increase auction revenues, by reducing the number of items available to the strong bidders. The quantity available for strong bidders can be reduced simply by setting aside one of the licenses to be auctioned only among the weak bidders. The set-aside license will be auctioned for just over $40, as $Weak_1$ will bid slightly more than $Weak_2$'s reservation price. After the set-aside, there are no longer enough licenses to satisfy strong-bidder demand, and these bidders accordingly will bid more aggressively for the remaining license. This remaining license will be auctioned for slightly more than $90, as $Strong_1$ will bid slightly more than $Strong_2$'s reservation price—and $30 more than it would bid absent the set-aside. Setting aside one license thus raises the government's expected revenue to slightly more than $130, an increase of $10. Despite increasing government revenue, the set-aside also reduces efficiency—one of the licenses ends up in the hands of a $60 valuer instead of a $90 valuer.[30]

B. *Bidding Credits Can Create Effective Set-Asides*

Like explicit set-asides, bidding credits can enhance government revenues by effectively reducing the quantity available to strong bidders. Consider a bidding credit that allows weak bidders to pay only 50 percent of their winning bids. Because of this 50 percent bidding credit, $Weak_1$ would be willing to bid

29. We assume that a single license will give the bidder sufficient capacity to serve all of the demand in the geographic area. Alternatively, we might have assumed that the FCC prohibits any firm from owning more than one license in a geographic area.

30. The set-aside correspondingly reduces the profits or, in game-theoretic terms, payoffs that the strong bidders would earn in the absence of a set-aside. The set-aside reduces the payoffs to the strong bidders by $60. $Strong_1$'s payoff decreases from $50 to $20: Without the set-aside, $Strong_1$ pays $60 for a license it values at $110 ($110 − $60 = $50) whereas with the set-aside $Strong_1$ must pay $90 ($110 − $90 = $20).

up to $120. Therefore, $Strong_1$ and $Weak_1$ would each win a license by bidding slightly more than $90 ($Strong_2$'s reservation price).[31] The government revenue from this auction would be approximately $135: $Strong_1$ would pay slightly more than $90, and $Weak_1$ would pay 50 percent of its bid, or slightly more than $45. The bidding credit reduces the quantity available to the strong bidders. Because neither strong bidder will bid up to $Weak_1$'s $120 subsidized reservation price, they will compete with each other for one license, driving its price to $90. The bidding credit generates more government revenue than the set-aside because $Weak_1$ must compete with $Strong_2$ rather than $Weak_2$ to win a license. Like the set-aside, the 50 percent bidding credit induces inefficiency by allowing $Weak_1$ to win a license instead of $Strong_2$; nonetheless, the government realizes more revenue than it would either with a traditional English auction or with a set-aside.

C. *Bidding Credits Can Create Intergroup Competition*

Properly calibrated bidding credits can simultaneously cause strong bidders to bid more aggressively and avoid inefficiency. With a 25 percent credit (rather than the previous 50 percent), $Weak_1$ will bid $80,[32] and the strong bidders will each win a license by bidding slightly more than this amount. The total auction revenue will be slightly more than $160. The 25 percent bidding credit induces intergroup competition as weak bidders raise the amounts that strong bidders must pay to win licenses. Absent any bidding preference, the strong bidders pay only $60 per license, but the bidding credit forces each strong bidder to increase its bid $20.[33]

D. *Affirmative Action Can Increase Expected Revenue When the Government Is Imperfectly Informed About Bidder Valuations*

The foregoing examples make clear that bidding preferences can enhance government revenues when the seller knows the reservation prices of the individual bidders. Imputing this knowledge to sellers, however, is unreasonable, not only because they seldom have this information, but also because if they did, knowledgeable sellers would maximize revenue by setting firm-specific reservation prices. For example, if the government knew the reservation prices of the strong firms, it would simply make $Strong_1$ and $Strong_2$ take-it-or-leave-it offers of slightly less than $110 and $90 respectively.

In this section, we show how bidding preferences can enhance revenue even when sellers are imperfectly informed about bidder valuations. When sellers do not know bidders' exact valuations, subsidizing weak bidders may allow a low-value bidder to buy a license for a low price, resulting in reduced revenue

31. $Weak_2$ would not bid more than $80, because winning at more than this price would force it to pay more than its reservation price of $40.

32. Bidding more than $80 would force $Weak_1$ to pay more than its $60 reservation price if it won a license ($80 × (1 − 0.25) = $60).

33. Giving the weak bidders a 33.33% bidding credit would further increase the government's revenue—$Weak_1$ would force strong bidders to bid at least $90 to win the auction. $Weak_1$ would bid $90 because $90 × (1 − 0.3333) = $60.